The gift of Mr Joseph Trumbull to his
Friend and Servant
John Adams. –

Mr. *Winthrop*'s
LECTURE
ON
EARTHQUAKES.

Adams 140.9
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A

LECTURE

ON

EARTHQUAKES;

Read in the Chapel of *Harvard-College* in
Cambridge, N. E. November 26th 1755.

On Occaſion of the great *EARTHQUAKE* which ſhook
New-England the Week before.

By *John Winthrop*, Eſq;

Holliſian Profeſſor of the Mathematics and Philoſophy at *Cambridge*.

Publiſhed by the general Deſire of that *Society*.

> Subterraneous caverns and vulcanos, if well conſidered, will be found to be wiſe contrivances of the Creator, ſerving to great uſes of the Globe, and ends of GOD's government. In all probability, theſe things may miniſter unto many ſecret, grand functions and operations of nature in the bowels of the earth.
> Dr. Derham's Phyſico-Theol.

BOSTON; New-England:
Printed and Sold by *Edes* & *Gill*, at their Printing-Office next
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N.B. March 12 about ¼ after two in the Morning, We had an Earthquake; resembling tho' not quite equal to that of 1755 which gave occasion to this Discourse, in Violence or Duration. —

A
LECTURE
On EARTHQUAKES.

YOU may juſtly expect, that the great EARTHQUAKE, which ſo lately [a] ſpread terror, and threatened deſolation throughout *New-England*, ſhould take me off from my ſtated courſe of lectures, to inquire into the probable cauſes of ſo formidable a phænomenon. The ſubject is curious, and at preſent engages the attention of many perſons; and the diſcuſſion of it may help to extend your views.

An Earthquake, you all know, is an agitation or ſhaking of ſome *conſiderable* part of the earth, and that by *natural* cauſes; in contradiſtinction to the ſhaking of a *ſmall* part of it by *artificial* methods. The degrees of this ſhaking are very various;—from the ſmall jarrings, which are but juſt perceptible, to thoſe violent ſucceſſions, which have altered the face of whole countries.

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[a] This great Earthquake happened on *Tueſday* the 18th of *November*, 1755, about a quarter after four in the morning. There was another much ſmaller ſhock an hour and quarter after this, viz. at $5^{h}\,29'$; and a third, on the *Saturday* evening following, at 27′ after 8. Since the reading of this lecture, there has been another ſmall ſhock, viz. on *Friday* the 19th of *December* in the evening, exactly at 10 o'clock; the ſky being then perfectly clear, and a very gentle gale at S. W. It was preceded by the peculiar noiſe of an Earthquake about 3 or 4 ſeconds, and the jarring laſted near as long; cauſing the window-ſhutters and door of the chamber, in which I then was, to clatter. Thoſe of my family, who were in a lower room, perceived nothing of the ſhake, though they heard the noiſe. Theſe are the only ſhocks that I have been ſenſible of; though it is ſaid, that many others have been felt in the Province of *New-Hampſhire*, ſince the firſt great one.

tries. Theſe ſhakings are for the moſt part (I believe, always) præceded or attended by an hollow rumbling noiſe, ſomething like what is called *heavy thunder*; which is uſually greater or leſs, according to the degree of the ſhake. Naturaliſts have diſtinguiſhed earthquakes into two kinds; one, when the motion is horizontal, or from ſide to ſide; the other, when it is perpendicular, or right up and down. This diſtinction may, for what I know, be juſt; and yet perhaps earthquakes more commonly conſiſt in a kind of *undulatory* motion, which may include both the others. For as a wave of water, when raiſed to it's greateſt height, ſubſides, and in ſubſiding ſpreads itſelf horizontally; ſo in like manner, a *wave of earth*, if I may be allowed the expreſſion, muſt in it's deſcent partake both of an horizontal and perpendicular motion at the ſame time. And for the ſame reaſon, it muſt have had both theſe motions in it's aſcent; but thoſe particles, which had been carried forward in one direction in the aſcent, will return in a contrary direction in the deſcent. This has been evidently found to be the caſe in the more violent earthquakes; and probably the reaſon why it has not been univerſally found ſo, was, the difficulty of diſtinguiſhing theſe two motions from one another, when each of them has been but ſmall. Though the ancient *Ægyptians* and *Chaldæans* are ſaid to have been able to foretell earthquakes, yet it is very certain, from all the accounts we have, that theſe agitations of the earth do no where obſerve any order or regular period in their returns; but at ſometimes, recur more frequently; at others, after longer intermiſſions. If therefore they pretended to foretell them at all, they muſt have done it, not from any knowledge they had of their nature and cauſes; but only by the vain arts of judicial aſtrology;—a kind of learning, it ſeems, which, futile as it is, was held in high repute among them. No countries, of which we have any knowledge, are exempt from theſe agitations; but ſome are more ſubject to them than others; and it is obſervable, that thoſe which abound moſt with combuſtible minerals, as foſſile coals, ſulphur, nitre, &c. are the moſt expoſed to them. Many of theſe countries, too, have certain mountains called *vulcanos*, which are almoſt perpetually burning, and throwing out fire, and ſmoke, and aſhes; their entrails probably conſiſting chiefly of ſuch ſort of minerals. It is obſerved, however, that about the time of an earthquake in thoſe places, theſe vulcanos rage more furiouſly, projecting ſtones and cinders to a great height in the air; and pouring out whole rivers of liquid fire, which carry ſuch a devaſtation, wherever they run, as no human art can either prevent or repair. Several ſuch there are in the *Molucca* iſlands in the *Eaſt-Indies*, almoſt under the equinoctial; and *Iceland*, under the polar circle, has four or five, beſides the noted *Hecla*. *Veſuvio* near *Naples* is very remarkable; but there is none more famous than that in *Sicily*, now known there by the name of *Monte Gibello*, as it was formerly by that of *Ætna*; whoſe eruptions VIRGIL has deſcribed in ſo pictureſque a manner, that I cannot forbear repeating a few lines from him.

> ———Horrificis juxta tonat Ætna ruinis:
> Interdumque atram prorumpit ad æthera nubem,
> Turbine fumantem piceo et candente favilla;
> Attollitque globos flammarum, et ſidera lambit.
> Interdum ſcopulos avulſaque viſcera montis
> Erigit eructans, liquefactaque ſaxa ſub auras
> Cum gemitu glomerat, fundoque exæſtuat imo.
>
> Æneid. III. 571. ſeqq.

This deſcription [b] of theſe phænomena is perhaps not exceeded by any extant; except by thoſe paſſages in the holy ſcriptures which aſcribe theſe effects, as true philoſophy does all thoſe which we call *natural* effects, to the agency of GOD. It is HE, 'who removeth the mountains, and they know not; who 'overturneth them in his anger; who ſhaketh the earth out of 'her place, and the pillars thereof tremble.' 'HE looketh on 'the earth, and it trembleth; HE toucheth the hills, and they 'ſmoke.' 'The pillars of heaven tremble, and are aſtoniſhed 'at HIS reproof.' Nothing can equal the ſublimity, the grandeur of theſe images. But to proceed.

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[b] For the ſake of Engliſh readers, Dr. TRAPP's tranſlation of this paſſage is here inſerted.

> ——— ' *Ætna* thunders nigh
> ' In dreadful ruins. With a whirlwind's force
> ' Sometimes it throws to heav'n a pitchy cloud,
> ' Redden'd with cinders, and 'nvolv'd in ſmoke;
> ' And toſſes balls of flame, and licks the ſtars.
> ' Sometimes with loud exploſion high it hurls
> ' Vaſt rocks, and entrails from the mountain torn;
> ' With roaring noiſe flings molten ſtones in air,
> ' And boils, and bellows, from it's loweſt caves.

That the earth has been, in all ages, and in moſt parts of it, ſubject to theſe agitations, hiſtory affords us but too many proofs. It is not, however, my deſign to enter into a detail of the diſmal events of this ſort, left upon record. I ſhall only extract from authentic accounts a few of the moſt ſtriking particulars, in order to give you ſome idea of the dire effects, which ſuch convulſions of the earth are capable of producing.

Imagine then the earth trembling with a huge thundering noiſe, or heaving and ſwelling like a rolling ſea:—now gaping in chaſms of various ſizes, and then immediately cloſing again; either ſwallowing up the unhappy perſons who chanced to be over them, or cruſhing them to death by the middle:—from ſome, ſpouting up prodigious quantities of water to a vaſt height, or belching out hot, offenſive and ſuffocating exhalations; while others are ſtreaming with torrents of melted minerals:—ſome houſes moving out of their places; others cracking and tumbling into heaps of rubbiſh; and others again, not barely by whole ſtreets, but by whole cities at a time, ſinking downright to a great depth in the earth, or under water:—on the ſhore, the ſea roaring and riſing in billows; or elſe retiring to a great diſtance from the land, and then violently returning like a flood to overwhelm it; veſſels driven from their anchors; ſome overſet and loſt, others thrown up on the land:—in one place, vaſt rocks flung down from mountains, and choking up rivers, which, being then forced to find themſelves new chanels, ſweep away ſuch trees, houſes, &c. as had eſcaped the fury of the ſhock; in another, mountains themſelves ſinking in a moment, and their places poſſeſs'd by pools of water:—ſome people running about pale, with fear, trembling for the event, and ignorant whither to fly for ſhelter; others thrown with violence down on the ground, not being able to keep on their feet; and others ſhrieking or groaning in the agonies of death:—even the brute creation manifeſting all the ſigns of conſternation and aſtoniſhment:—Imagine theſe things to yourſelves, and you will then have a view, though but an imperfect one, of ſome of thoſe images of horror and deſolation, which accompany the more violent earthquakes.

But I will dwell no longer on theſe tragical ſcenes. Thoſe of you, who are deſirous of farther information, may meet with it in the Philoſophical Tranſactions;[c] particularly in the accounts of thoſe horrible earthquakes, which almoſt deſolated the iſlands of *Jamaica* and *Sicily*, 63 years ago; in the latter of which it was computed, that about 60,000 perſons periſhed; which was very near one quarter of the whole number of inhabitants. To relieve you and my ſelf under ſuch melancholy proſpects, I will turn my thoughts to the theory of theſe moſt formidable phænomena, as ſoon as I have made two or three obſervations on the earthquakes we lately felt.

GOD be thanked, all earthquakes are not formidable in ſo high a degree. Thoſe of *New-England*, in particular, which have indeed greatly and juſtly alarm'd the inhabitants, have never deſtroyed them. For tho' this country, we know, has been viſited with earthquakes from it's firſt ſettlement by the *Engliſh*; yet, ſo far as my information reaches, not a ſingle life has been loſt by any of them; and perhaps never ſo much damage done to our buildings as by the laſt great ſhock: As to which I would obſerve,

Firſt, That it certainly began with an *undulation* of the earth, as I have been aſſured by ſome who were then awake; tho' I think it would not have been eaſily concluded from the effects, that the earth had had any other than an horizontal motion; thoſe effects which were generally taken notice of, being chiefly, if not only, ſuch, as a perpendicular motion would not, but an horizontal one would, have produced. Such, for inſtance, were the daſhing of liquors over the ſides of open veſſels; the over-

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[c] *Lowthorp*'s Abridgement, Vol. II. p. 400—419.

ſetting many things in houſes; and the throwing of bricks from off the tops of chimnies to ſome diſtance. In order to eſtimate the velocity with which ſome were thrown from my chimney, I meaſured the greateſt diſtance on the ground to which any of them had reach'd, and found it to be 30 feet; and the height of the chimney from which they fell was 32 feet. Now bodies fall thro' 16 feet nearly in one ſecond of time; and the times, in which they fall thro' other heights, are in the ſubduplicate ratio of thoſe heights. From whence it follows, that the velocity, wherewith thoſe bricks were thrown off, was that of above 21 feet in 1″ of time. For the ſubduplicate ratio of 32 to 16 is the ſame as the ſimple ratio of 30 to a little more than 21. It will be impoſſible, I believe, ever to determine with exactneſs the real ſpaces thro' which any of our buildings vibrated, in this reciprocating motion of the earth. It may be obſerv'd, however, that the ſhorter theſe vibrations are ſuppoſed to have been, the quicker or more frequent they muſt have been; the number of them in a given time being reciprocally as the length of each. Thus, for example, if each vibration had been of one foot in length, then there were 21 of them in 1″ of time; but if each were of 6 inches, then there were 42 of them in a ſecond; and ſo on. Poſſibly, ſome of theſe reciprocations might be as quick as thoſe of a muſical chord.

But it is not to be doubted, that the velocity, wherewith our buildings were agitated, was different in different places. It was different alſo, as I apprehend, at different heights. This I collect from the obſervation, that a key, which was thrown off a ſhelf in my houſe, was not thrown ſo far, in proportion to the height thro' which it fell, as the bricks were from the top of the chimney. Hence it appears, that our buildings were *rocked* with a kind of angular motion, like that of a cradle; the upper parts of them moving ſwifter, or thro' greater ſpaces in the ſame time, than the lower.[d] This perfectly agrees with the idea of an *undulatory*

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[d] That the vibrations of our buildings, and eſpecially of the higher parts of them, were in fact extremely ſwift, appears from ſome effects, which had not come to my knowledge, when I wrote the above paragraphs. 'The 'burſting of a diſtiller's ciſtern, by the agitation of the liquor in it; and the 'breaking

undulatory motion of the earth ; as you may clearly conceive by turning your thoughts to the caſe of a veſſel floating at reſt upon ſtagnant water, and then ſuddenly agitated by a great wave rolling under it. In the motion of aſcent, the maſt of the veſſel would be thrown forward, in the ſame direction as the wave was moving ; and in the motion of deſcent, backward, or in the contrary direction ; and in both theſe caſes, the top of the maſt would move thro' greater ſpaces than the bottom. As

' breaking off the ſpindle of the vane on *Faneuil-hall*, in *Boſton*,' are arguments of it. This ſpindle, if I am rightly informed, was a pine ſtick, of about 5 inches in diameter, at the place where it was ſnap't off ; and 10 feet in height ; and the weight of the vane on the top of it was about 30 pounds. But nothing more ſtrongly infers the exceſſive ſwiftneſs of theſe vibrations, than the bending of the wind-vanes on ſome high ſteeples. One at *Boſton* was bent at it's ſpindle 3 or 4 points of the compaſs ; and another at *Springfield*, diſtant about 80 miles in a right line weſterly from *Boſton*, was bent to a right angle ; as I was aſſured by an eye-witneſs. This effect ſeems to be owing to a ſmart ſhock upon theſe ſpindles, in a direction perpendicular to that in which the vanes happened to ſtand ; which in an inſtant gave them a very great velocity. The motion from below being given in the firſt place to the ſpindles, they were jerk'd forward ſo ſwiftly, that there was not time to have it communicated to the extreme parts of the vanes ; which therefore were left behind, and remain'd in their former places. This may be illuſtrated by the following inſtance. ' When a door is half open, and ' moving very freely on it's hinges ; if a piſtol be fired againſt it, the ball ' will go through the door, without moving it out of it's place : becauſe the ' motion of the ball is communicated but to a few parts of the door ; ' viz. only thoſe which the ball drives before it. Dr. DESAGULIERS's Experimental Philoſophy, Vol. I. p. 419. The reſiſtence of the air might alſo contribute to this effect. The reſiſtence, which a fluid makes to the motion of bodies in it, is, *cæteris paribus*, as the ſquare of their velocity. When the motion, then, is not very ſwift, a fluid affords a pretty eaſy paſſage to bodies moving in it ; but when the motion is ſo ſwift, that there is not time for the particles of the fluid to give way, and make room for the moving body, in this caſe a fluid will reſiſt as much as a ſolid. An inſtance of this we have in the book now cited, p. 420. ' A muſket being fired againſt ' water, the bullet was beaten to pieces upon the ſurface of the water. ' And thus in the preſent caſe, the velocity, attempted to be given by thoſe ſpindles to their vanes, may be ſuppoſed ſo vaſtly great, that the air might reſiſt their motion, in the manner of a firm, immoveable obſtacle ; which reſiſtence therefore would be equivalent to the ſtroke of an hard body againſt them. In either way of accounting for this effect, it is viſible, that the velocity, wherewith the tops of thoſe ſteeples vibrated, muſt have been extremely great.

As it is certain, that in the great ſhock, the earth had an horizontal motion; ſo it appears with the moſt ſenſible evidence to me, that in the ſhock we felt the *Saturday* evening following, at 27′ after 8, there was a perpendicular motion of the earth. I was then ſitting on a brick hearth, and felt the motion of the bricks diſtinctly under my feet. It was not a motion of the whole hearth together, either from ſide to ſide, or up and down; but of each brick ſeparately by itſelf. Now as the bricks were contiguous, the only motion, which could be communicated to them ſeparately, was in a perpendicular direction; and the ſenſation excited in me was exactly the ſame, as if ſome ſmall ſolid body, by moving along under the hearth, had raiſed up the bricks ſucceſſively, which immediately ſettled down again. The motion of the earth in this inſtance plainly appeared *undulatory* to me; and this ſhock, I apprehend, was occaſioned by one ſmall *wave of earth* rolling along, but not with a very ſwift motion. For the velocity of it's progreſs was conſiderably leſs than that of ſound, which moves about 13 miles in a minute; as appeared from hence, that the roar of this earthquake might be heard at leaſt half a minute before the ſhake was felt. Which alſo argues, that the ſhock began at ſome conſiderable diſtance from this place. The ſame remarks may be applied to the great ſhock; only this began with two at leaſt, if not three *waves*, of much greater breadth and height. The latter part of this ſhock was *tremulous*, conſiſting chiefly in vibrations which ſucceeded one another with extreme quickneſs; and, as I take it, was owing to the efforts of the earth to recover the poſition, out of which it had been violently thruſt, during the undulatory motion: Much in the ſame manner, as the reciprocations of a muſical chord are occaſioned by it's endeavours to reſtore it ſelf to that ſituation, which it had before it was ſtruck. As ſoon as the ſtroke, which bent it, ceaſes, the chord does not barely regain it's rectilinear figure, but bends itſelf almoſt as far the contrary way; and thus continues bending and unbending itſelf with great quickneſs, till it's motion is gradually deſtroyed, and at length it ſettles into a ſtate of reſt. Both theſe ſhocks, then, ſeem evidently to have been of the *undulatory* kind; and to have differed in degree only. [c] I would obſerve

Secondly, that the *duration* of the great ſhock was *longer* than has been uſually obſerved. If my memory fails me not, even thoſe earthquakes, which have brought on the moſt amazing cataſtrophes, have commonly done their execution in one or two minutes; whereas this ſhock with us laſted at leaſt four; taking in the whole of the time, from the firſt agitation of the earth, till it was become perfectly quiet; though the violence of the ſhock did not laſt above half ſo long. This I am aſſured of, partly from the obſervations of ſome Gentlemen, who were up, and looked on their watches, when it began and ended; and partly from my own, which were as follows. The preceding noon, I had adjuſted both my clock and watch, by a meridian line; and the following noon I found that the watch had kept time exactly. Being awaked by the earthquake, I lay till the violence of it ſeemed to be over, for the ſecond time; for it had a little abated before, as if it were going off, and then inſtantly began again with redoubled fury. Till then I forbore to riſe, becauſe the agitation was ſo vehement, that I concluded it would be very difficult, if not impracticable, to go from the bed to the chimney, without being thrown down; and therefore thought it beſt not to attempt it. The ſpace of time, in which I lay awake, I cannot think to be much, if any thing, leſs than 2′. This was the conjecture I formed at that time; though it being but conjecture, I would not lay very great ſtreſs upon it, were it not ſupported by concurring obſervations. On the ſecond abatement I roſe, and lighting a candle, looked on my watch, and found it to be 15′ after 4. The ſhock then was not quite over, but the windows continued rattling for about a minute longer, as near as I can remember; for the ſhock went off very gradually. As ſoon as I had looked on the watch, I went directly to the clock, which was in another chamber, that I might ſee whether that agreed with the watch; and found that it was ſtop'd at 4^h 11′ 35″. It's ſtopping, however, was not, immediately, owing to the violence of the ſhock, though ſeveral clocks, and watches too, at *Boſton* are ſaid to have been ſtop'd by it; but to the following accident. Having ſome time before uſed a pretty long glaſs tube, in a particular experiment, I had ſhut it up in the clock-caſe for ſecurity; and this tube, being overthrown by the earthquake, lodged againſt the pendulum, and ſtop'd it's motion. By this accident, the beginning of the earthquake, I conceive, is determined with all the exactneſs that can be deſired; for, ſo far as I can learn, the firſt ſhake was violent enough to overſet ſo tall, ſlender a body, and ſtanding in a poſition ſo near a perpendicular, as that tube; and it was impoſſible for the pendulum to make one oſcillation, after the tube had ſtruck againſt it. Now from the time when the clock ſtop'd, to my looking on the watch, it was about 3′½; and the jarring was not quite over, till about a minute after this: So that I think I ſpeak within bounds, when I ſay, that this ſhock with us laſted at leaſt 4′. In other places, it's duration might poſſibly be different. I obſerve

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[c] I take the laſt ſhock, on the 19th of *December*, to have been alſo *undulatory*. For it's being more ſenſible above ſtairs than below, as was obſerved in Note [a], is an indication, that the motion of the houſe was of the *rocking* kind, and this implies *undulation* in the earth.

It may not be amiſs to obſerve here, that theſe undulations of the earth are not to be ſuppoſed to follow one another in ſo orderly a manner, as the waves of the ocean often do: nor that they all move forward exactly in one direction. They rather reſemble the agitations of a *tumbling* ſea, whoſe ſurges riſe and fall irregularly, and follow different courſes in different places; and in the ſame place too, at different inſtants of time. This appears from that remarkable effect, of ſome chimnies being partly turned round. One of mine looked as if it had been twiſted, quite down to the roof.

Thirdly, as to the *courſe* of this earthquake, that it ſeems to have been nearly *from N. W. to S. E.* I was informed a few minutes after the ſhock, by a perſon who was upon the *common* in this town at the time, that the noiſe began about the N. W, and came on from thence, and paſs'd away toward the S.E; and other accounts, which I have ſince met with, agree with this. Thoſe who were in ſuch clear, open places could make the beſt judgement in this matter; for ſuch as were within doors, or ſurrounded with buildings, might eaſily be miſled by the various reflections of the ſound. I am induced to give the greater credit to this information, by what I obſerved my ſelf. For the key before ſpoken of, as thrown from off a ſhelf in my houſe, was found at a place on the floor, which bore very near N. W. of the place from which it fell ; though the ſituation of it before it's fall was ſuch, that it might have been thrown in ſeveral other directions as well as that, had the courſe of the earthquake been different. [f] Let

[f] An account which we have lately received from the *Weſt-Indies* agrees very well with the ſuppoſition, that our earthquake proceeded from hence ſoutheaſtward. The account is, ' that on the 18th of *November*, about two o'clock in the afternoon, the ſea withdrew from the harbour of St. *Martin*'s, leaving the veſſels dry, and fiſh on the banks, where there us'd to be 3 or 4 fathom water ; and continued out a conſiderable time, ſo that the people retired to the high land, fearing the conſequence of it's return ; and when it came in, it aroſe 6 feet higher than uſual, ſo as to overflow the low lands. There was no ſhock felt at the above time.' As this extraordinary motion of the ſea happened about 9 hours after we had the great ſhock, it ſeems very likely to have been occaſioned by the ſame convulſion of the earth. Now if this earthquake went off ſoutheaſtward into the *Atlantic*, it would paſs conſiderably to the eaſtward of St. *Martin*'s ; and it is plain that, in fact, it did not reach that iſland, there being no ſhock felt there. The motion of the ſea, then, was owing to a great agitation raiſed at a conſiderable diſtance, in ſome part or other of the ocean, where the earthquake paſſed ; and from thence propagated to that iſland. Nor is the length of time greater than what ſeems to be neceſſary for this purpoſe. The earthquake itſelf, at the rate it moved with us, would be ſome hours in going from hence to the latitude of St. *Martin*'s. For it has been already obſerved, that it's progreſs was ſlower than that of ſound ; and ſound would be about two hours and a quarter in moving to ſuch a diſtance. The reſt of the 9^{h} might well be ſpent in conveying this motion excited in the water, from the place where it was excited, to St. *Martin*'s ; for the waves raiſed hereby cannot be ſuppoſed to have moved with near the velocity of ſound.

It is to be regretted, that we have had no good accounts of the time, when the earthquake happened at different places on the continent, whoſe longitudes and latitudes are known ; which might have enabled us to form a more exact judgement of this matter.

A very ingenious Gentleman having given it as his opinion, ' that the earthquake ſeems to have come from the S. W,' I think my ſelf obliged to conſider what he has offered upon this point. His words are, ' Moſt accounts we have from the S. W. make the ſhock conſiderably ſooner there, than we had it here, and than it was felt to the N. E. of us ; ſo much ſooner, that the difference of longitude will ſcarce help us at all in accounting for it :' In which, as I humbly conceive, there is a miſtake. For, allowing the difference of longitude, the expreſſions uſed in the accounts from the S. W. are preciſely ſuch as might be expected, in caſe the earthquake was felt there at the ſame inſtant that it was here. I ſuppoſe it is ſufficiently

Having made the obſervations propos'd, let us now attempt
to

ently evident from what has been ſaid above, that the earthquake began with us at $11'\frac{1}{2}$ after 4, within a very few ſeconds of time. Now our meridian is to the E. of *New-Haven* about $8'\frac{1}{2}$;—of *New-York*, about $12'\frac{1}{2}$; and of *Philadelphia*, about $17'\frac{1}{2}$. Conſequently, when it was $11'\frac{1}{2}$ after 4 with us, it was 3′ after 4 at *New-Haven*; and it wanted a minute of 4 at *New-York*. Now the accounts from both thoſe places are, that they had the earthquake *about four* o'clock. Again; at this ſame moment of time, it wanted 6′ of 4 at *Philadelphia*; and their account is, that the earthquake happened *between three and four* o'clock.

I do not remember any account of the time, from the N. E; unleſs that from the veſſel on the *Atlantic*, 70 leagues E. of *Cape-Anne*, may be reckoned for one. The people on board this veſſel are ſaid to have felt the ſhock at *half paſt four*. Now 70 leagues on the parallel of *Cape-Anne* make the difference of meridians to be 19′. So that when it was 11′ after 4 with us, it was exactly *half paſt four* at that veſſel.

Thus, all theſe accounts agree perfectly with the ſuppoſition, that the earthquake was felt at the ſame time in theſe ſeveral places. But I am far from affirming, that it really was ſo. I am indeed inclined to think, that there was no great difference in the time of it's being felt here, and in the places to the S. W. For it ſeems moſt likely, that it reached at the ſame time to all places which lay in a line perpendicular to it's courſe. So that if it came from about the N. W, as I believe it did, I ſhould think, that all the places beforementioned, *Boſton*, *New-Haven*, *New-York*, and *Philadelphia*, which bear almoſt S. W. and N. E. from each other, muſt have felt it nearly at the ſame time. I was careful to note the time, when we had it, as exactly as I could; in hopes that, by comparing it with the like accounts from diſtant places, we might be able to judge, both of the courſe of the earthquake, and the velocity of it's progreſs. But all the accounts of the time, which I have yet ſeen, are ſo very lax, that no juſt concluſions can be drawn from them, with reſpect to either of theſe points. To eſtabliſh any thing of this ſort, the minutes at leaſt, if not the ſeconds, ſhould be made certain.

It is worthy of remark, that two, of the five great earthquakes which we have had, have gone nearly in the ſame track, as this laſt did. The firſt of all, which was on *June* 2. 1638. is ſaid by the Hiſtorian, to 'come from the northward, and paſs ſouthward.' By the deſcription given of it, it was very much like our late earthquake, only not quite ſo violent. 'The 'noiſe and ſhakes of the earthquake, *October* 29. 1727. ſeem'd,' it is ſaid, 'to come from the northweſtward, and to go off ſoutheaſterly; and ſo the 'houſes ſeemed to reel.' As to the great earthquakes of 1658 and 1663, we have no account of the courſe which they went in. But from the other three, it may be reaſonably conjectured, that the centre, or place in which our earthquakes originate, lies in ſome part of *Canada*; or perhaps beyond it. — March 12th 1761. another Earthquake happen'd which may perhaps enable us to determine whereabouts these Earthquakes originate, and what Course they take. for as all Canada is now in English hands, we may have accounts from Montreal, Quebeck &c. and the several Places upon the River St Lawrence, of what time this Earthquake happen'd, its Direction and degree of Violence. —

to trace out the cauſes of theſe great phænomena. [g]

That the agents, which are able to produce effects ſo extraordinary as thoſe before recited; which can heave up ſuch enormous maſſes of matter, and put into the moſt vehement commotion vaſt tracts of land and ſea, of many hundred miles in extent;—that the agents, I ſay, which can do all this, and more, muſt be very powerful, will not admit of a doubt. Now we know of nothing in nature more powerful than the particles of certain bodies converted into vapor by the action of fire. Fire then, and proper materials for it to act upon, it is probable, are the principal agents in this affair. And what greatly ſtrengthens the probability is, an obſervation before-mentioned, that thoſe countries, which have burning mountains, are moſt ſubject to earthquakes; and that theſe mountains rage with uncommon fury, about the time when the circumjacent countries are torn with convulſions;—an argument this, that the eruptions of ſuch mountains, and earthquakes, are owing to one and the ſame cauſe. But we muſt be more particular.

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[g] Several accounts of the late earthquake having been already publiſhed by different hands, particularly very full and diſtinct ones by the Rev. Doctors CHAUNCEY and MAYHEW; I think it needleſs for me to add any thing farther upon this head, except the following ſhort notes.

1. Dr. MAYHEW ſpeaks of ‘ ſuch a great white froſt being upon the ‘ ground in the morning, as he had not obſerved for many years paſt.’ I took notice of it likewiſe; and, when it was melted, meaſured it; and found that it covered the ground to the depth of $\frac{17}{1090}$ parts of an inch; which is almoſt double of any white froſt we have had for ſeven years paſt, and about 5 or 6 times as great as we commonly have.
2. The barometer and thermometer underwent no alteration at the time of the earthquake: Only, my barometer, which has an open ciſtern of quick-ſilver, was ſo agitated, that part of the quick-ſilver was daſh'd over the ſides of the ciſtern, and ſcattered upon the floor. This ciſtern was a cylindric cup, whoſe ſides were an inch higher than the ſurface of the quick-ſilver.
3. I have received undoubted intelligence from a Gentleman in that neighbourhood, that the report we had of ‘ a prodigious chaſm made in the ground at ‘ *Newington* in *New-Hampſhire*, of 60 rods in length, and 2 feet in breadth,’ is a pure fiction; and that it had no other foundation than this (if this indeed can be called a foundation for ſuch a ſtory) that a ſtone fence in that town, ſtanding upon a ſandy ground, was ſhaken down by the earthquake; and the force of the falling ſtones, having beat up the ſand on each ſide, made ſome appearance of an hollow in the middle.

1. The earth is not ſolid throughout, but contains within it many large holes, pits and caverns; as is agreed by all Natural Hiſtorians. There are very probably alſo long, crooked, unequal paſſages, which run winding through a great extent of earth, and form a communication between very diſtant regions.[h] Some

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[h] The obſervation here made concerning the great length of ſubterranean canals has received a new and ſtrong confirmation by the account, inſerted in note [f], of the agitation of the ſea at St. *Martin*'s; and a ſtronger ſtill, by another account we have more lately received of a ſurprizing flux and reflux of it at *Barbadoes*, on the firſt of *November* laſt, at two o'clock in the afternoon; which was about 6 hours after that terrible earthquake, which made ſuch havock at *Lisbon*, and the neighbouring parts of *Portugal* and *Spain*. This account, as it was publiſhed in our News-papers, is as follows. *Extract of a Letter from* Barbados, Nov. 13, 1755. "The firſt of this Inſtant, about 2 o'Clock, P. M. the Tide having then ebbed one Hour, in a ſtark Calm, there was, of a ſudden, to the great Surprize of all the Inhabitants, a Flux of Water, that roſe to the Height of 5 Feet and upward, and as ſuddenly it returned to the Sea; this Flux and Reflux was perform'd every 6 or 7 Minutes, and ſo continu'd 'till 10 o'Clock, tho' the Violence abated gradually from 5 o'Clock: So that in that ſmall Space of Time, the Sea flux'd and reflux'd, upwards of 60 Times." Extraordinary commotions in the ſea were likewiſe obſerved, the ſame day, on the weſtern coaſts of *Europe* and *Africa*, and at a conſiderable diſtance from the ſhore. One 'veſſel in Lat. 25. 30 'N. and Long. 16. 15 W. from *London*, about half an hour after 9 A. M. 'was violently agitated for the ſpace of 3 minutes by an earthquake, tho' 'not damaged,' as we were told in our News-papers. This veſſel was then under a meridian half an hour to the W. of *Lisbon*, and at the diſtance of about 1000 miles from it; and the time, when it felt the ſhock, was an hour earlier than they had it at *Lisbon* and *Cadiz*; and therefore, if this was the ſame ſhock as that, it was an hour in moving from the place of this veſſel to thoſe cities. 'At *Lisbon*,' we are told, 'half an hour after the ſhock, 'which came between 10 and 11 o'clock in the forenoon, and continued 'about 2 minutes, the tide came in and aroſe about 20 feet higher than 'common, by which a few people were drowned. And at *Cadiz*, that ſoon 'after the ſhock, which was at 11 in the forenoon, and laſted about 3 'minutes, they ſaw from the ſhore a heavy ſea (about half a mile diſtance) 'coming on, which did conſiderable damage to the ſhipping, and when it 'broke, made great deſtruction in the city:—That about a quarter of an 'hour after, there came a ſecond ſea as awful; and about the ſame ſpace 'after, came a third more awful, which did prodigious damage; and great 'numbers of people were loſt.' Theſe extraordinary agitations in the ocean, which all happened on the firſt of *November*; and another of the ſame

of theſe cavities are dry, and contain nothing but air, or the fumes of fermenting minerals; in others, there are currents of water.

2. This globe is a very heterogeneous body. Beſides the two grand diviſions of it into ſolid and fluid parts, each of theſe is again diviſible into an indefinite number of others. Although our knowledge of the earth reaches but a little way below it's ſurface, yet ſo far as we have penetrated, it appears to be a *compages* of a vaſt variety of ſolid ſubſtances, ranged in a manner which to us ſeems to have not much of regularity in it. Here we find earths, ſtones, ſalts, ſulphurs, minerals, metals, &c. and a great number of inferior ſpecies under each of theſe general heads, blended and intermingled with each other. Many of theſe are combuſtible, or of a texture proper to be turned by fire into flame and vapor. And beſides the pure elementary water, if there be any ſuch, the aqueous parts of the globe receive peculiar

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ſame kind on the 18th, which was obſerved at St. *Martin*'s, as is related in note [f]; we ſhall endeavour to account for in note [aa]. p. 24.

Here now we have an earthquake extending it's effects acroſs the *Atlantic*. An amazing diſtance truly for an earthquake! And ſuch as I do not remember to have met with any account of, in hiſtory. Our earthquake reached 1900 miles; whereas this reached almoſt twice as far.

But though this latter earthquake was of greater extent than the former, perhaps it did not much, if at all, exceed it in the degree of violence. Indeed, the damage done by it at *Lisbon* appears to have been vaſtly greater than any ſuſtained by us; though we have not yet had an exact account of the particulars. But this was probably owing, not altogether to the greater violence of the ſhock, but partly, if not chiefly, to their manner of building. I am informed by a Gentleman, who is well acquainted with that city, that the buildings are very high, many of them being of 7 ſtories; and chiefly of ſtone, laid in clay. A poor cement indeed! which can never bind ſtones together with any tolerable firmneſs. And on ſuppoſition that their earthquake was of the ſame ſpecies with ours, that is, *undulatory*, the great height of thoſe buildings expoſed them to much greater agitations, than if they had been lower. (See p. 10.) It is no wonder then, if their houſes were ſhaken to pieces, though the ſhock were not more violent than what has been felt in other places, where much leſs damage has been done. An earthquake that could give ſo ſmart a blow, as ours did to ſome wind-vanes (See note [d]) muſt be ſufficient, one would think, to demoliſh ſuch a city in a few minutes; ſo as ſcarcely to leave one ſtone upon another. Had *Boſton* been built in that manner, probably at this day it would have been little better than an heap of ruins.

peculiar tinctures from the beds and veins through which they run; ſo that perhaps there may be almoſt as many ſorts of waters, as there are of ſolid ſubſtances. Thus, ſome waters are charged with ſulphureous particles; ſome, with particles of iron; and others, with thoſe of other minerals. And the ſubterraneous rivers and ſtreams, thus impregnated with different particles, may, by their confluence, produce an almoſt infinite variety of mixtures in the earth. Probably, this promiſcuous diſpoſition of materials, in the bowels of the earth, may be neceſſary to the growth of bodies in it; for in the judgement of ſome of the moſt eminent philoſophers, particularly the excellent Mr. BOYLE, even the hardeſt, inorganized bodies, as ſtones, metals, &c. do, in their proper way, grow within the earth, as truly as vegetables grow on it's ſurface, or animals in their parent animals. And to the ſame end ſeems to conduce

3. The heat within the bowels of the earth. Heat, it is well known, is a grand agent in moſt natural productions; and the inner parts of the earth are ſufficiently furniſhed with it. Some parts indeed, as the vulcanos, are actually on fire and burn; but there is, moreover, an heat without flame, diffuſed through the interior regions of the earth. This is evident from the inſtance of hot ſprings, and from the warmth which is always found at great depths, as in the bottoms of mines.

4. There ſeems to be an inexhauſtible ſource of this heat in the attractive powers, which Sir ISAAC NEWTON has ſhewn to belong to the particles of matter. For, heat conſiſting in a peculiar kind of inteſtine motion of the parts of bodies; whatever tends to produce this motion in bodies, will cauſe them to grow hot. Now ſuch a motion may be produced, by the particles of different bodies ruſhing together, in virtue of their attractive powers; of which that great man has given a very copious collection of inſtances in the 31ſt *Queſtion* at the end of his *Opticks*, whither I muſt refer you. In ſome of them, not only a very ſudden and violent heat, but an actual flame, is produced, by the bare mixing of two cold bodies together; and that, even without the preſence of the air, which we find abſolutely neceſſary to our culinary fires. So in a remarkable experiment, (firſt made, I think, by Dr. SLARE) when a certain ' compound

‘ ſpirit of nitre is poured on half it's weight of any ponderous ‘ oil of vegetable or animal ſubſtances, the liquors grow ſo ‘ very hot in mixing, as preſently to ſend up a burning flame.’ [i] At the firſt trial, ſo ſmall a quantity, as ‘ a drachm of this ſpirit, ‘ being poured upon half a drachm of ſuch oil, *in vacuo*, to ſee ‘ what effect would enſue ; the mixture in the twinkling of an ‘ eye made a flaſh like gun-powder, and blew up the exhauſted ‘ receiver, whoſe diameter was ſix inches, and depth above ‘ eight ; all who were preſent being aſtoniſhed at the unexpected ‘ event.’ There is alſo ſo ſtrong an attraction between iron and ſulphur, that ‘ even the groſs body of ſulphur powder'd,’ continues Sir Isaac, ‘ and with an equal weight of iron filings and ‘ a little water made into paſte, in a few hours grows too hot to ‘ be touch'd, and emits a flame. And by theſe experiments ‘ compared with the great quantity of ſulphur with which the ‘ earth abounds, and the warmth of the interior parts of the ‘ earth, and hot ſprings, and burning mountains, and with damps, ‘ mineral coruſcations, &c. we may learn that ſulphureous ‘ ſteams abound in the bowels of the earth, and ferment with ‘ minerals, and ſometimes take fire with a ſudden coruſcation ‘ and exploſion.’ But to ſet this curious doctrine in it's full light, it would be neceſſary to repeat that whole *Queſtion* ; which indeed highly deſerves it, would the time permit. For it would then appear, that there is a very great variety of bodies, which being mixed together, produce ſo ſtrong an efferveſcence, as to emit inflammable fumes. Thus, to mention one inſtance more, when iron is diſſolving in a mixture of oil of vitriol and common water, there inſtantly ariſes a great heat and violent ebullition, with fumes copiouſly exhaling ; which are ſo very inflammable, that, being ſet on fire, they go off at once like a gun, with a great exploſion. Having thus ſeen what a perpetual ſource of heat there is in theſe powerful, active principles, continually operating within the bowels of the earth; let us next inquire, what effects may be expected from it. Therefore

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[i] *Newton*'s Opt. p. 353. This compound ſpirit of nitre was made by diſtilling equal parts of nitre and oil of vitriol. The oil uſed in Dr. *Slare*'s firſt experiment was that of carraway ſeeds. A full account of theſe experiments, by Dr. *Slare* himſelf, may be ſeen in *Lowthorp*'s Abridgm. Vol. III. p. 352—366.

5. It is a known property of heat to expand bodies, to rarefy them, and enlarge their dimenſions; and, when raiſed to an higher degree, to ſeparate their parts, and make them fly from each other; as in ſome meaſure appears already from the inſtances mentioned under the foregoing article. This effect heat has upon ſolid as well as fluid bodies;—upon the hardeſt, as well as the ſofteſt. It is obſervable here, that ſuch particles as cohere by the ſtrongeſt attraction, do moſt forcibly repel one another, when they are once ſeparated by heat. And when the heat is intenſe, and the particles of the heated body are prevented from flying away, till they become thoroughly hot; it will require very ſtrong veſſels to hinder their burſting forth with a violent exploſion. Thus, a ſingle drop of common water, incloſed in a glaſs bubble, and laid upon the fire; which, as it becomes hot, will burſt the bubble, with a report ſcarce inferior to that of a piſtol. And water in larger quantities has been heated to that degree, as to rend in ſunder very ſtrong veſſels of iron, in which it has been endeavoured to be confined. What the conſequence then would be, of a great body of water's ſuddenly making it's way into a flaming cavern, whoſe ſulphureous or bituminous fires are not extinguiſhed but inraged by water; and of it's being there, almoſt inſtantaneouſly, converted into vapor; your own imaginations may eaſily repreſent to you. [*] This, it is very likely, has ſometimes been the caſe with reſpect to theſe famous vulcanos, *Ætna* and *Veſuvio*; both which border on the ſea. You ſee here what water may do; but there are many other bodies, which cohere more ſtrongly, as ſulphur and nitre, for example, whoſe vapor is ſtill more powerful than that of water. This is evident from the compoſition of gun-powder; a very ſmall quantity of which, when turned into vapor, every one knows, is able to remove any obſtacle that oppoſes it's expanſion, and to burſt the firmeſt rocks. The paſte abovementioned, made of powdered ſulphur and iron filings, if put a few feet under ground, will by degrees cauſe the earth over it to heave and crack, to let out the flame; thus making an artificial earthquake. And therefore, if a water,

ſaturated with ſulphureous particles, ſhould in it's paſſage under ground ſoak into a large bed of iron ore, or a ſtrong chalybeate water into a bed of ſulphur; the mixture would doubtleſs perform *in great*, what this experiment does in miniature. A vitriolic water mixing with iron, if in ſufficient quantities, would be followed with the like effect. But no mixture of this nature appears ſo ſurprizing as Dr. SLARE's, which did not require ſo much as the preſence of the air to inkindle it. From this ſmall mixture, which was but one drachm and an half, a force was generated in an inſtant, by the mutual colliſion of thoſe active liquors, far exceeding the weight of the atmoſphere that preſſed down the receiver; which in that experiment amounted to about 420 pounds. I ſay, *far exceeding*; for the receiver was not barely raiſed, but ' with a much greater force ' blown up,' as Dr. SLARE expreſſes it. We have no right indeed, that I know of, to ſuppoſe all the ſame ſorts of bodies, both ſolid and fluid, in the bowels of the earth, as chemiſtry has furniſhed us with; but ſeveral things induce us to believe, that in thoſe dark receſſes, impenetrable as they are to mortal eyes, bodies are prepared, by a kind of natural chemiſtry, which very much reſemble many of our chemical preparations, and are poſſeſſed of the ſame eſſential properties. To be ſure, there are not wanting, in thoſe lower regions, all the degrees of heat, which a Chemiſt could deſire for any of his proceſſes. If then two bodies, of the like nature as the ſpirit and oil uſed in this experiment, ſhould be mingled together in due quantity, though in the cloſeſt ſubterraneous vault, which neither contained any genuine air, nor could admit any; I need not ſay, that an earthquake muſt be the conſequence.

You have now, I ſuppoſe, before you the general cauſes of earthquakes. You have ſeen that there are in the bowels of the earth inflammable materials, of various kinds, and in large quantities; ſome in the form of ſolid or liquid bodies, and others in that of exhalations and vapors; that there are alſo powerful principles conſtantly at work, which are capable of inkindling theſe materials into an actual flame; and that the vapor generated from ſuch flame will endeavour to expand it ſelf on all ſides with immenſe force. If now theſe inflammable vapors be pent up in cloſe caverns, ſo as to find no vent till they are collected in a large quantity; ſo ſoon as they take fire in any part, the flame will ſpread itſelf, wherever it meets with materials to convey it, with as great rapidity, perhaps, as it does in a train of gunpowder; and the vapors produced from hence will ruſh along through the ſubterraneous grottos, as they are able to find or force for themſelves a paſſage; and by heaving up the earth that lies over them, will make that kind of progreſſive ſwell or *undulation*, in which we have ſuppoſed earthquakes commonly to conſiſt; and will at length burſt the caverns with a great ſhaking of the earth, as in ſpringing a mine; and ſo diſcharge themſelves into the open air. [aa] Theſe vapors may poſſibly ſometimes infect the air, and bring on peſtilential diſtempers, which have been ſaid to be conſequent upon great earthquakes. Not that

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[aa] The extraordinary commotions of the ſea, related in the foregoing notes, having happened within a few hours of the great earthquakes; one of which ſhook *Spain* and *Portugal*, and the other, *New-England* with ſome of the neighbouring parts of *America*; will naturally be aſcribed by every body to thoſe earthquakes, or at leaſt to the ſame cauſes as thoſe earthquakes are. Now for my part, I can hardly perſuade my ſelf, that the bare agitations of the earth, at thoſe times, could be great enough, to put the ſea into ſuch vehement commotions, as it appears to have been in, by thoſe relations. To account for theſe things ſatisfactorily, it ſeems to me that we muſt have recourſe to ſuch an *eruption* of the vapors which cauſed thoſe earthquakes, as is ſpoken of in the paſſage above. At thoſe times, theſe furious vapors, impatient of reſtraint, muſt have continued to drive along through their ſubterraneous paſſages, till they found ſome place, where the top of the caverns, which contained them, was not of ſufficient ſtrength to confine them; and there they would burſt out of their dungeons, and ſpring up into day. The eruptions, which cauſed thoſe uncommon motions of the ſea that ſurpriſed the inhabitants of *Barbadoes* and St. *Martin*'s, were very probably made in the *Atlantic* ocean, to the eaſtward of the *Weſt-India* iſlands, and near the ſame latitudes; and, until we hear whether the like commotions were obſerved elſewhere, about the ſame time, we may well enough ſuppoſe, that the places of theſe eruptions were nearer to thoſe iſlands, than to any other land. Now to aſſiſt the Reader in forming a conception of what probably paſſed in the ocean on thoſe great occaſions, I ſhall lay before him two or three facts, relating to the force of fired gun-powder, and the reſiſtence of water; taken from the before cited work of Dr. DESAGULIER'S, pp. 420, 421. The Dr. tells us, that ‘ being with ſeveral other perſons in a great barge upon the ‘ *Thames*, playing off ſome fire-works on a rejoicing day, it happen'd that a ‘ water-

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‘ water-rocket (whoſe property is to go under water ſeveral times and riſe ‘ again, and at laſt burſt on the top of the water) came up, when it was ‘ ready to burſt, under the ſtern of the barge, being thereby prevented from ‘ coming up to the ſurface of the water; and burſting where it was, gave ‘ the barge a great ſhock, and ſenſible lift, though there was much leſs than ‘ an ounce of powder to make it. Another of theſe rockets in it's laſt riſe, ‘ ſtopping under the middle of a ſmaller barge, broke there, and made ſo ‘ great an hole in the barge's bottom, that in a very ſhort time the barge was ‘ half full of water. After this, to try the effect of the exploſion of gun‘ powder under water; the Dr. loaded a water rocket, ſo that it ſhould ‘ break under the water, and having ſet fire to it, threw it into a pond, that ‘ covered an acre of ground: And ſo great was the ſhock, that ſeveral per‘ ſons, who ſtood round the pond, felt it like a momentaneous earthquake.' Now if ſo inconſiderable a quantity of powder, fired juſt under the ſurface of water, could have ſuch effects as theſe; what muſt have been the commotion, when the vapors, which were able to ſhake ſuch great extents of land and ſea, as we are ſure were ſhaken in theſe earthquakes, made their way, with united force, through the vaſt body of water that lay over them? No doubt, the water foam'd, and boil'd, and raged with inconceivable fury, and was agitated into overgrown, mountainous waves. The firſt effect of the eruption probably was, that all the water, which lay directly over the ſpot where the bottom of the ocean gaped to let out the vapors, was blown right up, almoſt like a compact body, to a great height in the air. The bottom doubtleſs cloſed again as ſoon as the vapors were diſcharged; but there muſt have been a pit or cavity left in the ocean, in the place deſerted by the water:—of what dimenſions it is impoſſible for us to ſay; though, from what followed it ſeems, they muſt have been very conſiderable. The next ſtep would be, that the neighbouring water would ruſh in from all ſides to fill up the vacuity; firſt, from the nearer parts; and then by degrees from the remoter; and by that means form a ſpacious concave all around, on the ſurface of the ocean; the centure of which would be this pit. The motion of the water deſcending to fill ſuch a pit, was what, I ſuppoſe, might draw off the water from the ſhore of St. *Martin*'s; which was the firſt circumſtance obſerved there. The water, by thus deſcending to fill the pit, having fallen below it's proper level, would next be raiſed above it, erecting itſelf into a mountain over the place where the pit was made; and then by falling and riſing alternately in this place, would communicate an undulatory motion all around it: And the waves thus excited would be more numerous, and of greater breadth, as the dimenſions of the pit firſt made were larger. Mean time, the water, thrown up at the beginning in

I can give credit to all the reports of this ſort, which have been handed about; many of them having been propagated by writers of an aſtrological turn, who have been as ready to attribute diſtempers to the configurations of the planets, and to the appearance of comets, as to earthquakes.

By this time, enough has been ſaid, I ſhould think, to convince you, that the earth contains within itſelf the ſeeds of earthquakes in great abundance. And all theſe things being conſidered, it may ſeem rather a wonder that we have no more earthquakes, than that we have ſo many. The cauſes of earthquakes are inceſſantly at work; and although it may require a courſe of years [bb] to ripen the proper materials to that pitch, as that

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a body into the air, would by it's weight fall down in cataracts, and add greatly to the confuſion. A motion like this, once begun, muſt needs be propagated to very conſiderable diſtances, before it could be intirely loſt; and that to a degree ſufficient, I ſhould think, to cauſe ſuch great waves, and to ſuch a number, as were obſerved at the places before-mentioned. Whether this, or ſomething like this, might not probably have been the proceſs of theſe extraordinary ſcenes in the ocean, I ſubmit to the judgement of the Reader. And if he ſhall be of this opinion, he will doubtleſs make a pauſe, and reflect on the great goodneſs of HEAVEN, in cauſing the vapors to break forth in the ocean;—a place, where they could do the leaſt hurt. The effects which muſt have followed, had theſe impetuous blaſts been directed againſt the foundations of a great and populous city, his own imagination will paint to him in livelier colors than I can pretend to do.

It is neceſſary to ſuppoſe, at leaſt two ſuch eruptions in the *Atlantic* on the firſt of *November*. For it is utterly incredible, that the waves excited by one only, however great in degree, or in whatever part of the ocean, it be ſuppoſed, could reach to places at ſuch diſtances from each other, as *Cadiz* and *Liſbon* are from *Barbadoes*. The inundations at *Cadiz* and *Liſbon* were probably occaſioned by one and the ſame eruption, which, by the violence of them, ſeems to have been at no great diſtance from thoſe cities. But that at *Barbadoes* muſt have been occaſioned by another eruption, happening a few hours later; and ſeems, by the expreſſions uſed in the relations, to have fallen far ſhort of thoſe in *Europe*, in point of violence. From whence we ſhould argue, that this eruption happened at a conſiderable diſtance from that iſland: Becauſe, from the great number of waves, or fluxes and refluxes, we muſt argue, that the commotion in the centre or place of eruption, which excited thoſe waves, was vaſtly great.

[bb] Beſides ſeveral leſſer earthquakes, there have been five great ones in *New-England*, ſince the arrival of the *Engliſh* in 1620; which, at a medium, is one

that they can force for themſelves a paſſage thro' the earth; yet it is reaſonable to expect, that they will from time to time be collected in ſuch quantities, and ferment to ſuch degrees, as to make theſe exploſions unavoidable. As therefore our globe has been ſubject to ſuch concuſſions from the earlieſt accounts of antiquity, we have no room to doubt but that it will continue to be ſo, as long as the preſent frame of nature ſubſiſts. For this we may be aſſured of, that though that impriſoned vapor be diſcharged into the open air, which, by its ſtruggles to eſcape, has cauſed an earthquake; yet the fermenting minerals, from which it was generated, will be continually ſupplying new quantities of the ſame; and even thoſe very minerals may from time to time be re-produced, as they are conſumed; as was before obſerved. Thus we ſee, that in the very ſtructure and conſtitution of this globe, proviſion has been made to continue theſe agitations of it, at proper intervals of time, during the whole period of it's exiſtence in it's preſent form; and that in every climate, from the equator to the pole. This ſuggeſts a reflection, with which I ſhall cloſe the preſent diſcourſe. It is this: That

Though theſe exploſions, and conſequent concuſſions of the earth, have indeed occaſioned moſt terrible deſolations, and in this light may juſtly be regarded as the tokens of an incenſed Deity; yet it can by no means be concluded from hence, that they are not of real and ſtanding advantage to the globe *in general*. Multitudes, it is true, have at different times ſuffered by them; multitudes have been deſtroyed by them; but much greater multitudes may have been every day benefited by them. The all-wiſe Creator could not but foreſee all the effects of all the powers he implanted in matter; and, as we find in innumerable inſtances (and the more we know of his works, the more ſuch inſtances we diſcover) that he has eſtabliſhed ſuch laws for the government of the world, as tend to promote the good of *the whole,*

Earthquakes of [illegible]
ing advantage [illegible]
Globe. [illegible]
from [illegible]

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one in about 27 years. But they have not happened at equal diſtances of time. About the year 1660, they were pretty frequent; but I find no mention of any from 1670 till that memorable one in 1727; between which there was an interval of 57 years.

whole, we may reaſonably preſume, that he has done it in this caſe as well as others. To me, at leaſt, the argument on this ſide the queſtion, drawn from the general analogy of nature, appears to have more force, than any that I have ſeen offered on the other. For there is nothing, however uſeful, however neceſſary, but what is capable of producing, and in fact has produced, damage, in ſingle inſtances. It were endleſs to particularize here; I ſhall therefore only mention one or two things by way of ſpecimen. The power of gravity,—a power of ſuch indiſpenſable importance, that without it the ſyſtem of nature could not ſubſiſt a moment, has yet proved the deſtruction of multitudes. The wind, ſo neceſſary for the purpoſes of navigation, as well as to purge the air, which would otherwiſe ſtagnate and putrefy,—how often has it riſen to ſuch a pitch, as to overthrow houſes, and wreck veſſels? by which means thouſands have periſhed. Even thunder and lightning, which, next to earthquakes, are the moſt terrible phænomena of nature, are yet univerſally allowed to be neceſſary to free the atmoſphere from a certain unwholſome ſultrineſs, which often infects it. Other inſtances of the like ſort I leave to your own reflections: and would rather obſerve, that the world is governed by *general* laws; and general laws muſt, from the nature of them, be liable ſometimes to do hurt. However, laws of this ſort are ſufficiently vindicated, not only as *wiſe,* but as *good,* if upon the whole they produce a *maximum* of good; (to borrow an expreſſion from the Mathematicians;) and this, it is in the higheſt degree probable, all the laws of nature do. It may be added, that as in the animal body, the evacuations, which are of abſolute neceſſity to maintain life and health, do yet ſometimes run to ſuch extremes as to prove mortal; ſo in like manner, theſe exploſions of ſubterraneous vapor, whoſe effects have ſometimes been ſo fatal, may, notwithſtanding this, be highly conducive, and even indiſpenſably neceſſary, to the good of this globe in general. The exploſions themſelves, as well as the laws, in conſequence of which they are produced, may be neceſſary on various accounts;

and

however necessary [illegible]
[illegible] productive [illegible]

gravity

wind

thunder

and particularly to the carrying on the more ſecret and noble works of nature within the entrails of the earth. [cc] Let me dilate a little on this matter.

By the inceſſant action of gravity and other attractive powers, and by the perpetual conſumption of fluids, the earth becomes continually more and more hard, compact and denſe. Now an openneſs or looſeneſs of contexture, to a certain degree, in the earth, is neceſſary to carry on the operations of nature within it. So that on the ſuppoſition that mineral, metalline, and other ſubterraneous bodies grow within the earth, it ſhould ſeem that the earth muſt become gradually leſs and leſs fit for the production of them. Since then the direct, immediate, and moſt general effect of earthquakes is, by ſhaking to looſen and diſunite the parts of the earth, and to open it's pores, it ſeems agreeable to reaſon to infer, that this is the end *primarily* aimed at in theſe concuſſions. But you will take notice, that I ſpeak here only of *phyſical* or *natural* ends. For though I make no doubt, that the laws of nature were eſtabliſhed, and that the operations of nature are conducted, with a view, *ultimately*, to *moral* purpoſes; and that there is the moſt perfect coincidence, at all times, between GOD's government of the *natural* and of the *moral* world; yet it would be improper for me to enter into theſe diſquiſitions at this time, ſince my province limits me to conſider this ſubject, only in the relation which it bears to *natural philoſophy*. It is in the *phyſical* ſenſe alone that I ſay, the disjoining the parts of the earth, and opening it's pores, may be the end primarily aimed at in earthquakes, as ſuch mutations in the earth may from time to time become neceſſary to the production of ſubterraneous bodies; and perhaps this end could not be effectually anſwered by leſs forcible methods. This point may receive ſome light, if not proof, from the operations of agriculture. We find it neceſſary, by ploughing, digging, &c. to break the clods of the ground, to comminute and even pulverize it, in order to fit it for the purpoſes of vegetation; and we find it neceſſary to renew theſe labors every year. Now the uſe and tendency of theſe artificial operations may bear ſome analogy to thoſe of the greater operations of nature, which we are ſpeaking of. And indeed, it is not in the leaſt degree improbable, that ſuch a looſening of the parts of the earth may promote even the growth of vegetables on it's ſurface, as well as of minerals in it's bowels; it being now well known, that all vegetables, the ſmaller as well as the larger, ſhoot ſome fibres of their roots to vaſtly greater depths, than thoſe to which any of our inſtruments of tillage ever penetrate. This, it is likely, may be one reaſon of the wonderful fertility, for which *Ætna* and *Veſuvio* have been ſo generally and ſo highly celebrated. Again; it may be neceſſary now and then, to have ſuch ſubterraneous vapors, as are generated by fermentation, diſcharged up into the air; as their continuance below, in the caverns of the earth, might be an impediment to thoſe important proceſſes which are there carrying on. But thoſe very vapors, which might obſtruct ſome ſorts of natural proceſſes, while below the ſurface of the earth, may as much advance others, when above it. We know that in many caſes of the fermentation of bodies, eſpecially of ſuch denſe ones as ſalts and minerals, air is plentifully *abſorbed*; and that in many others, it is as plentifully *generated*: So that great part of the exhalations thrown out by earthquakes may be true, permanent air, and deſigned to recruit what has been abſorbed by bodies here on the ſurface. And perhaps the grounds, on which the great NEWTON founded his 'ſuſpicion, [dd] that the fineſt, the moſt ſubtile, 'and moſt ſpirituous parts of our air, and thoſe which are moſt 'neceſſary to maintain the life of all things, come chiefly from 'the comets'; may equally ſupport another ſuſpicion, that ſome ſuch particles of air may be derived alſo from ſubterraneous eruptions. For among the almoſt infinite variety of particles which are thrown out of the earth in theſe eruptions, it is moſt likely, that if ſome are noxious, others will be ſalutary. It may alſo be neceſſary from time to time to have the ſubterraneous ſtreams diverted from their former courſes into new ones: partly, that different places in the lower regions may be watered by them; and partly, that the waters themſelves, by paſſing through different beds or chanels, may alter their properties, [ee] and convey new tinctures to different places.

[cc] It is not impoſſible that ſome may think it ſtrange to have any thing ſaid, that ſeems at all to abate the horror which many people have of earthquakes, as if *all* of them were *nothing but ſcourges* in the hand of the ALMIGHYT; and may be fearful, leſt the cauſe of religion ſhould be diſſerved hereby. But of this there is not, in my apprehenſion, the remoteſt danger. The idea here exhibited, while it exalts the wiſdom and goodneſs, does not in the leaſt detract from the majeſty, or from the juſtice, of GOD. And the terror, which an earthquake never fails to carry with it, will be ſufficient to ſecure the intereſts of religion, ſo far as they are to be ſecured by the influence of fear; even though ſuch a phænomenon be repreſented in the moſt favorable light that truth will admit of.

[dd] *Newton*'s Princip. p. 515.

But however theſe things may be; whether all the foregoing conjectures be well founded, or not: If theſe exploſions and concuſſions be, as it is next to certain that they are, the neceſſary and inevitable conſequences of ſuch laws of nature, and ſuch powers in matter, as our globe could not well ſubſiſt without; this ought to ſilence all the complaints of thoſe who ſuffer either loſs or terror by them; as well as all the objections, which men of ſceptical minds have been diſpoſed to make, upon this head, to the order of Providence. It ought, in reaſon, to do this, though we ſhould never be able to point out all the particular advantages reſulting from them. For, it is plain, they may be beneficial in a thouſand other ways, than we, ſhort-ſighted mortals, may pretend to gueſs at.

To ſum up all in a word. This is a MIX'D ſtate; in which there is ſuch a variety of purpoſes, *natural* as well as *moral*, in proſecution at the ſame time, that there may be nothing, perhaps, in the material world, that is ſimply and abſolutely *evil*;— nothing, but what, under the direction of infinite wiſdom, power and beneficence, is, in ſome or other of it's conſequences, productive of an over-balance of *good*.

Upon the whole. How 'wonderful in counſel', how 'excellent in working' is that BEING, who can bring good out of the greateſt evils; and can anſwer intentions, the moſt widely differing, by one and the ſame diſpenſation of His providence!

[ee] Some wells near me have had the quality of their waters much mended ſince the earthquake.

The END.

APPENDIX.

APPENDIX,

Concerning the Operation of Electrical *Subſtance in* EARTHQUAKES; *and the Effects of Iron Points.*

A little tract having lately appeared among us, under a reſpectable name, hinting at a different cauſe of earthquakes, from that which is delivered in theſe papers; it is deſired and expected, I find, by ſeveral worthy Perſons, that I ſhould here take ſome notice of it. Th[illegible] I ſhall endeavour to do, with all the reſpect that belongs to venerable characters, conſiſtent with that ſuperior regard which is due only to truth. When I compoſed the foregoing diſcourſe, I thought it of more importance to explain to my pupils what I took to be the real cauſes of earthquakes, than to enter into an examination of "the many fine but uncertain *Hypotheſes* of the "projecting ſort of Philoſophers both ancient and modern;" to do which, with any degree of exactneſs, would have required a diſcourſe by itſelf. Philoſophy, like every thing elſe, has had it's faſhions, and the reigning mode of late has been, to explain every thing by ELECTRICITY. It is not long, ſince we were amuſed with pompous accounts of the wonderful effects of electricity in the practice of phyſic. It was extoll'd as a perfect *catholicon*; and repreſented as affording the moſt eaſy, and, at the ſame time, the moſt effectual means of conveying into the body, the active particles of all medicines, emetic, cathartic, alterative, &c. and as curing, or at leaſt relieving, almoſt inſtantaneouſly, the moſt obſtinate and intractable diſorders, which the human body is liable to; gout, blindneſs, deafneſs, dumbneſs, and what not! But this affair is pretty well over for the preſent. Now, it ſeems, it is to be the cauſe of earthquakes. Electricity indeed is at this day certainly known to be a much more extenſive principle in nature, than was ſuſpected a few years ago; and to have a hand in the production of effects, where it was thought to have no concern. It muſt not, however, be concluded from hence, that it is the ſole principle of natural effects, and that it does every thing. It is true, the very ingenious Mr. FRANKLIN of *Philadelphia* has, with ſingular ſagacity, and, in my opinion, with happy ſucceſs, accounted this way for the phænomena of thunder and lightning; and has made diſcoveries upon this ſubject, which are not only extremely curious in ſpeculation, but of high importance in practice. But this is no argument, that electricity is alſo the cauſe of earthquakes. In the tract before me, P. 21. we are indeed told, that "the *Electrical Subſtance* ſubſiſts "and moves to and fro in *different Parties* or *Collections* in the *Bowels* of "the *Earth*, as well as in the *Clouds* of the *Air*. And ſo waving about in "*different Parties* in the *Earth* below, though *by Divine Direction*, and *ſur-*

“ *rounding other ſubſtances*, as in the *air* above ; when a *greater party* comes “ within the ſtriking diſtance of *another*, a ſhock is immediately effected : and “ in *proportion* to the *quantities* of thoſe *ſeveral parties*, and the *other ſub-* “ *ſtances ſurrounded by them*, is the *ſhock* in the *earth*, either *leſs* or *greater*.” And “ all this” with more is ſaid to be “ argued from *Analogy*.” But that *analogy* does not take place here ; that the two caſes of lightning and earthquakes are no way parallel ; and that the electric ſubſtance, when in the bowels of the earth, is in circumſtances eſſentially different from what it is, when in the clouds of the air ; will, I think, plainly appear, by taking a brief view of the known laws of electricity, ſo far as they can be thought to relate to this ſubject. Not that I here take upon me to maintain a negative, or to aſſert abſolutely, that electricity cannot poſſibly be, directly nor indirectly, concerned in the production of earthquakes. Neither would I aſſert this of magnetiſm, any more than of electricity. I cannot ſay how far the unknown cauſes of theſe powers may be connected together, and with the cauſes of other attractive and repulſive powers ; and therefore do not pretend to know all the poſſible effects of either of them ; or what remote influence they may have, in virtue of ſome yet undiſcovered properties, upon any of the phænomena of this lower world. What I would be underſtood to mean, then, is this, that according to the laws of magnetiſm and electricity, ſo far as they have been hitherto diſcovered, it is inconceivable to me, how earthquakes can be accounted for by them. At preſent, we are concerned only with electricity.

The laws of electricity are ;—that every body is either an *electric per ſe*, or a *non-electric* ;— that electrics *per ſe* are incapable of receiving electricity by communication from others, and therefore cannot have the quantity of electrical ſubſtance, which they naturally contain, augmented ; nor yet, on the other hand, can they have it diminiſhed ;— that non-electrics may receive electricity by communication ; but in order to this, it is fundamentally neceſſary, that they be intirely *ſupported* by, and ſurrounded with, electrics *per ſe*. For if a non-electric, which is to receive electricity by communication, or, as it is commonly called, to be *electriſed*, touches another non-electric, or even if it is very near it ; the electricity, received by the firſt, will be communicated to the ſecond ; and if there be more than two, to the third ; and ſo on. And if this line of non-electrics reaches to the ground, all the electricity received will go away into the earth ; and none of the non-electrics will be electriſed at all. But if any number of non-electrics touching, or very near, one another, be terminated on all ſides by electrics, they may then receive and retain electricity for ſome time. For the electric ſupporters, being incapable of receiving this communicated electricity, ſtop the progreſs of it, and confine it to the non-electrics. All this will appear plainer, eſpecially to thoſe who have ſeen electric experiments, by ſingling out a particular inſtance. Thus, a metalline tube, ſuch as is commonly uſed in electric experiments, and is called a *conductor*, is a non-electric, and is incapable of being rendered electrical, by any action immediately upon it. A glaſs globe is an electric *per ſe*, and may have it's electricity excited by rubbing it ;

and if it be very near the non-electric conductor, it will communicate it's electric virtue to that, provided the conductor be properly ſupported. It muſt be ſupported by nothing but electrics *per ſe*, ſuch as glaſs, wax, roſin, &c. or by lines of ſilk or hair. Such ſupporters, as they cannot receive the virtue from the glaſs globe, will ſtop it from running off the conductor, which by that means becomes electriſed. But if the conductor be not intirely ſupported in this manner ; if there be the ſmalleſt line of communication, by the intervention of non-electrics, between the conductor and the earth, altho' it were but the fineſt wire; or a ſingle thread of hemp or flax, or any thing that is wet ; all the electricity, given by the globe to the conductor, will run off that way, and be loſt in the earth ; and the conductor will ſhow no ſigns of electricity at all. It is known alſo, that the air, which ſurrounds this earth, is an electric *per ſe ;* as appears from hence, among other conſiderations, that if it were non-electric, it would be impoſſible for us ever to electriſe a conductor, or any thing elſe ; unleſs it were placed *in vacuo*. For in that caſe, all the virtue, given to the conductor, would run off by the air ; as, in damp weather, it does by the watery vapors floating in the air, which are non-electric bodies. It was before obſerved, that electrics cannot have their ſhare of the electric ſubſtance increaſed or diminiſhed ; but non-electrics may, when duly ſupported : And the whole effect of abundance of the electric experiments, that are made in *courſes*, is nothing more than this ; that when one non-electric is brought within a certain diſtance, called the *ſtriking diſtance*, of another non-electric, which contains a different proportion of the electric ſubſtance from the former ; that which contains the moſt will impart ſo much to that which contains the leaſt, as to make it equal in both. And the tranſition of the electric ſubſtance, from one of theſe bodies to the other, will be attended with a flaſh and a report ; which will be greater, in proportion as the abſolute quantity of the electric matter accumulated in one of the bodies is greater, and as the difference between the quantities in the bodies imparting and receiving is greater. And much in the ſame proportion will the ſtriking diſtance be greater too.

It is eaſy now to ſee, that, though lightning may be accounted for upon theſe principles, earthquakes cannot. For clouds, which are collections of watery, that is, of non-electric vapors, being *intirely ſupported and ſurrounded by air*, which is an electric *per ſe*, are capable of having more or leſs than their natural quantity of the electric ſubſtance. And therefore, when a cloud, containing more or leſs than it's natural quantity of the electric ſubſtance, approaches the earth ; or when two clouds, containing unequal quantities of this ſubſtance, approach one another ; the conſequence will be, a diſcharge of electric ſubſtance from that body which contained the moſt of it, into that which contained the leaſt, till it becomes equally divided between them ; which diſcharge will be accompanied with a flaſh of lightning and clap of thunder. But where is the *analogy* between this caſe in the air, and what may be ſuppoſed to paſs in the bowels of the earth, to cauſe earthquakes ? To make out any thing like an analogy, we muſt ſuppoſe, *firſt*, two huge non-electric bodies under ground, which, for ſome earthquakes, muſt be hundreds, if not thouſands, of miles in extent; and *ſecondly*, that each of theſe non-electrics is *intirely ſupported and ſurrounded by electrics* per ſe. The *firſt* of theſe ſuppoſitions has no difficulty in it; becauſe this terraqueous globe conſiſts almoſt wholly of non-electrics; but where to find ſuch electric ſupporters for theſe vaſt conductors, as are required in the *ſecond*, is a point, I humbly conceive, attended with very great difficulty. And yet, without this, it is impoſſible that either of theſe non-electrics can have more or leſs than it's own natural quantity of electric ſubſtance. For though we were told of its ‘ waving about in different parties in ‘ the earth below,’ yet there can be no ſuch thing; unleſs the ‘ *Divine Di-* ‘ *rection*,’ here introduced, ſhould in this caſe ſuſpend or ſet aſide the eſtabliſhed laws of nature; that is, ſhould act *miraculouſly*. But this will hardly be ſuppoſed: Becauſe, to have recourſe to *miraculous* interpoſitions of the ‘ Divine ‘ Direction,’ is to put an intire end at once to all reaſonings about electricity, or earthquakes, or any other natural phænomena. There can therefore, I ſay, be no ſuch thing as this ‘ waving about of the electric ſubſtance in different ‘ Parties in the earth below,’ ſo long as the ‘ Divine Direction’ continues to operate according to the eſtabliſhed laws of electricity: It being a certain truth, that whatever quantity of this electric ſubſtance is communicated to any non-electric body, it is equally diffuſed in an inſtant throughout the whole of that body. Thus, the virtue of the glaſs globe, though applied only to one end of the conductor, is in a moment ſpread all over it, and throughout it; and the conductor becomes equally electrifed in every part. There can, therefore, be no inequality of electric ſubſtance in the non-electric bodies of which this globe is compoſed, excepting only in thoſe which are intirely ſurrounded by electrics *per ſe*. Through all the reſt of the globe, the electric ſubſtance will be equally and uniformly diffuſed. Now if we could even find electric *ſupporters* for theſe vaſt *conductors* of a thouſand or two miles in extent, a very great difficulty would ſtill remain, which is, that this very circumſtance of having electric ſupporters on all ſides, without which no non-electric can have more than it's own natural quantity of electric ſubſtance thrown into it, nor any withdrawn from it, will, in the bowels of the earth, effectually prevent either of theſe alterations. The reaſon of this will appear plainer, I believe, by a particular inſtance, than by a long explanation. Suppoſe a glaſs bottle of water to be ſhut up perfectly tight with a glaſs ſtopple. Here will be a non-electric intirely ſurrounded with an electric. If this water had more than it's natural quantity of electric ſubſtance thrown into it, before it was ſtop'd up, the glaſs covering would keep it in; or if it had leſs, the ſame covering would prevent more from entring into it out of the neighbouring bodies. After the bottle is ſtop'd, the glaſs, which now ſurrounds the water on all ſides, by cutting off all communication between the water within the bottle and other non-electrics without, is an effectual bar in the way of any alteration. No more of the electric ſubſtance can, after this, enter into the bottle, or come out of it. And thus if, in the bowels of the earth, there be a non-electric *intirely ſurrounded* with electrics, it can have no additional quantity of electric ſubſtance thrown into it, nor any drawn out of it; the electries, which ſurround it, preventing the paſſage of this electric ſubſtance, either from without, inwards; or from within, outwards. And the caſe will be the ſame, if the non-electric be *not intirely ſurrounded* with electries. For then, if any quantity of the electric ſubſtance were attempted to be thrown into the non-electric, it would not remain there, but would inſtantly ſpread itſelf into the neighbouring non-electric bodies; and if any were attempted to be drawn out, it's place would be immediately ſupplied out of the neighbouring bodies. Thus it appears, that there can be ‘ no unequal diſtribution ‘ of this ſubſtance in the earth;’ and conſequently, by this Gentleman's own confeſſion in p. 20, ‘ nothing to produce any concuſſions there.’

For brevity's ſake, I have inſiſted only on this ſingle circumſtance of the neceſſity of electric ſupporters. When this difficulty is cleared up, there are others to be offered.

But the moſt exceptionable part is yet to come. It is the Poſtſcript in p. 23. which runs thus.

‘ P. S. The more *Points* of *Iron* are erected round the *Earth*, to draw the
‘ *Electrical Subſtance* out of the *Air*; the more the *Earth* muſt needs be
‘ charged with it. And therefore it ſeems worthy of Conſideration, Whether
‘ *any Part* of the *Earth* being fuller of *this terrible Subſtance*, may not be more
‘ expoſed to *more ſhocking Earthquakes*. In *Boſton* are more erected than any
‘ where elſe in *New-England*; and *Boſton* ſeems to be more dreadfully ſhaken.
‘ O! there is no getting out of the mighty Hand of GOD! If we think to
‘ avoid it in the *Air*, we cannot in the *Earth*: Yea it may grow more fatal.’

When I firſt read this Poſtſcript, I was both ſurpriſed and concerned:—ſurpriſed, to find ſo many miſtakes in ſo few lines; and concerned, for the ill effects it would probably have. For I could ſee no other effects of it, but that it would fill with unneceſſary terrors the minds of many perſons, who were not well enough acquainted with the laws of electricity, to diſcover the miſtakes: And that it would diſcourage the uſe of the *iron-points*, which were erecting in *Boſton* and elſewhere; and which, by the bleſſing of GOD, might be a means of preventing many of thoſe miſchievous and ſorrowful accidents, which we have ſo often ſeen to follow upon thunder ſtorms. In order therefore to guard, as much as I can, againſt the ill effects juſt mentioned, I ſhall now lay open, though as briefly as poſſible, the principal of theſe miſtakes.

1. Strictly ſpeaking, it is a miſtake to ſay, that ‘ points of iron erected ‘ round the earth draw the electrical ſubſtance out of the *air*.’ For the air, being an electric *per ſe*, obſtinately retains it's own quantity of this ſubſtance, and will not part with it to any other body, They do indeed draw it out of the *clouds* in the air; which, being non-electries, can part with ſome of it. But even this they muſt be ſaid to do, only in a qualified ſenſe; and not ſo univerſally, as the firſt words of this P. S. ſeem to intimate. For

2dly, I

[illegible]

2dly, I appeal to every Reader, whether the idea, moſt obviouſly conveyed by thoſe words, be not this, that theſe iron points do, by a *conſtant and perpetual action*, keep drawing the electric ſubſtance out of the air, and overcharging the earth with it. Now this is far from being the caſe. They never draw it out of the air, or, more properly, out of the clouds in the air, but when thoſe clouds have more than their due quantity of it, and the earth, leſs; and conſequently, it is impoſſible, that they ſhould ever overcharge the earth with it at all. The only thing they can do is, to reſtore to the earth it's juſt quantity, when it is undercharged. But ſuppoſing they did conſtantly draw this electric ſubſtance out of the air into the earth, yet

3dly, They could never fill '*any part* of the *earth* fuller of *this terrible* '*ſubſtance*'; nor conſequently 'expoſe any one part more than another to *more* '*ſhocking earthquakes*.' For how much ſoever of this terrible ſubſtance be ſuppoſed drawn out of the air into any particular part of the earth, it cannot remain collected there, but will inſtantly ſpread itſelf all around into the neighbouring parts which have leſs of it, and thus will be reſtored to an equality every where.

4thly. I know no reaſon to think, that '*Boſton* was more dreadfully ſhaken' than other towns. Some of the effects of the earthquake may have been more conſiderable, for their number, there than elſewhere; but the reaſon of this is, not that 'in *Boſton* are more *points* of *iron* erected than any where elſe in '*New-England*', but that there are more *brick houſes* erected there. For the effect of a ſhock is more conſiderable upon brick-work than upon wood-work. The reaſons of this are obvious; and that it is ſo in fact, plainly appeared by our chimnies being every where more ſhattered than any thing elſe: Though this was in part owing to their being the higheſt parts of buildings.

5thly. I ſhould think, though with the utmoſt deference to ſuperior judgements, that the pathetic exclamation, which comes next, might well enough have been ſpared. 'O! there is no getting out of the mighty hand of GOD!' For I cannot believe, that in the whole town of *Boſton*, where ſo many iron points are erected, there is ſo much as one perſon, who is ſo weak, ſo ignorant, ſo fooliſh, or, to ſay all in one word, ſo atheiſtical, as ever to have entertained a ſingle thought, that it is poſſible, by the help of a few yards of wire, to 'get out of the mighty hand of GOD.'

6thly. The poſtſcript proceeds. 'If we think to avoid it' [the mighty hand of God] 'in the *Air*, we cannot in the *Earth*: Yea it may grow more 'fatal.' Upon which I obſerve, that if the hypotheſis in queſtion were right; if earthquakes were indeed cauſed by 'any parts of the earth being fuller of '*this terrible ſubſtance*' than they ought to be; it would follow, not that iron points make 'the mighty hand of God grow more fatal', or 'expoſe thoſe 'parts to more ſhocking earthquakes'; as is here moſt groundleſsly inſinuated: But it would follow, that iron points would be of great and moſt admirable uſe, in preventing earthquakes as well as thunder and lightning. For it muſt be obſerved.

This Exclamation was very popular for the audience in general then thought the Iron [illegible] consider Thunder and Lightning as well as Earthquakes, only as Judgments, Punishments, Warnings &c & have no Conception of any Use they can serve in Nature. —

I have heard some Persons of the highest Rank among us, say, that they really thought the Erection of Iron Points, was an impious Attempt to rob the Almighty of his Thunder, to wrest the Bolt of Vengeance out of his Hand! and others, that Thunder, was design'd, as an Execution upon Criminals, that no Mortal can stay. That the Attempt was foolish as well as impious. — And no Instances, even those of Steeples struck, where Iron Bars have, by accident convey'd the Electricity as far as they reach without damage, which one would think would carry some Conviction, ~~[illegible]~~ have no Weight at all!

obſerved, that theſe iron points have, not only a power of *drawing* electric ſubſtance out of the clouds into the earth, but an equal power of *throwing off* this ſame ſubſtance out of the earth into the clouds; which latter power they exert, as often as the former: according to Mr. FRANKLIN's obſervations, to whom we are indebted for the diſcovery of *both* theſe powers of points. This latter power the Poſtſcript has intirely overlooked. The truth is: If a cloud have more than it's due quantity of electric ſubſtance, theſe points will draw the redundant part of it down into the earth; but if it have leſs, the points will *throw off* enough out of the earth into the cloud to ſupply the deficiency. If then it were poſſible for earthquakes to be cauſed by the earth's being more charged with electric ſubſtance than it ſhould be, and the air's being charged leſs; the iron points would ſtand ready to *throw off* the ſuperfluous part from the earth into the upper regions of the air; and thus, by removing the cauſe of earthquakes, would take away the effect.

I have now conſidered what this remarkable Poſtſcript tells us 'ſeems worthy of conſideration.' I have taken no notice of ſeveral other things in this piece which ſeem liable to juſt exception; but hope I have fully vindicated the character of theſe innocent and injured *iron-points*; and have ſhewed, that all apprehenſions of danger ariſing from them are perfectly groundleſs and chimerical.

Cambridge, Decemb.
20. 1755.

J. W.

An Additional Article to Notes in Page 17.

4. As to the limits of our great ſhock; I have very lately been informed, that it was felt at *Annapolis-Royal* in *Nova-Scotia*; though in a much leſs degree than with us. It ſhook off a few bricks from the tops of ſome chimnies; but was not perceived by veſſels upon the water. And a Letter from *Halifax*, which I have ſeen, ſays, 'The earthquake, which happened in the 'weſt, extended itſelf to this place, though ſcarcely perceivable here.' Thus, *Halifax* ſeems to have been very near the N. E. limit.

For the other limit, towards the S. W. my information is, that it was felt on the eaſtern ſide of *Cheſapeak* Bay in *Maryland*; and not on the weſtern ſide.

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☞ *The Reader is deſired to read* centre *for* centure *in p. 25 line* 10 *from the bottom; and to excuſe any ſmaller miſtakes.*

this Invention of Iron Points, to prev[illegible] anger [illegible] has met with all that opposition from the Superstition, affectation of Piety, and Jealousy of new Inventions, that Inoculation to prevent the Danger of the Small Pox, and all other usefull Discoveries, have met with in all Ages of the World.

I am not able to satisfy myself, whether the very general if not universal apprehension of Thunder, Earthquakes, Pestilence, Famine &c are designed merely as Punishments for sins and Warnings to forsake, is natural to Mankind, or whether it was artfully propagated, or whether it was derived from Revelation.

An Imagination that these Things are of no Use in Nature but to punish and alarm and arouse Sinners, could not be derived from real Revelation, because it is far from being true, tho some Persons can be persuaded to think so.